Tracing the Shadowy Origins of Nuclear Contraband

KARLSRUHE, GERMANY—When German police raided the home of Alfred Jäckle in May 1994, they were looking for counterfeiting material, but they found something far more disturbing: a vial containing a reddish radioactive powder. The police knew whom to call: the European Commission's Institute for Transuranium Elements (ITU) in this city near the French border. Nuclear sleuths at ITU discovered that the powder was red mercury, a Soviet-made plutonium-laced amalgam that analysts believe was designed to reduce the amount of plutonium necessary for a fission reaction. Although police seized only 6 grams of plutonium in Jäckle's home—far too little for a bomb—the incident provided a chilling reminder that the former Soviet nuclear legacy is far from secure (see main text).

Founded in 1963 to investigate the basic properties of plutonium and uranium, ITU has earned a reputation over the past decade as the go-to lab for probing the shadowy origins of seized nuclear materials. Unmasking a substance is the easy part; tracing it back to the source is far more difficult. A team of ITU scientists led by physicist Ian Ray uses cutting-edge techniques to examine how enrichment, irradiation at nuclear power plants, and radioactive decay alter the isotopic composition of nuclear materials.

The most famous case involving the lab occurred in August 1994, when police seized a steel suitcase containing 560 grams of dark-gray, radioactive powder after a Lufthansa flight from Moscow landed at the Munich airport. The arrests of three men—two Spaniards and a Colombian—at the airport as they claimed the illicit baggage ended a successful sting aimed at disrupting an alleged international smuggling ring. ITU scientists were given the task of puzzling out the exact nature of the nuclear material in the suitcase and, more importantly, where it came from. Their investigation revealed that the powder contained 363 grams of plutonium, 87% of which was plutonium-239—weapons-grade material. ITU has confirmed that the seized plutonium originated in Russia but for legal reasons cannot reveal the lab's identity.

So far, ITU has investigated more than 20 cases of suspected smuggling. Most of the work involves routine investigations into incidents of contamination. For instance, in 1997, the lab determined that a radioactive half-meter steel bar found at the Karlsruhe port had been part of a fuel assembly used in a Russian breeder reactor. The high-quality steel was destined for sale at a scrap yard, says Ray.

By German law, ITU has 24 hours to make an initial assessment; detained suspects must be charged within that time or released. The first step involves submitting a specimen to high-resolution gamma spectrometry to measure the energy of the gamma rays it emits. "Gamma radiation is like a fingerprint," says ITU physicist Herbert Ottmar, with different isotopes emitting rays at distinct energies. Uranium and plutonium, for example, shed low-energy gamma rays. Using this technique, ITU researchers can give a rough indication of whether the material is weapons grade: uranium containing more than 20% of the uranium-235 isotope, or plutonium containing more than 81% of plutonium-239. If the contraband is fuel pellets, their dimensions can point to the source reactor type.

To obtain more precise information about the material's composition, ITU scientists dissolve the material in nitric acid and separate uranium and plutonium from other elements using ion exchange chromatography. Mass spectrometry then reveals their exact isotopic composition.

Within 24 hours, the scientists must draw up a report outlining the elemental and isotopic compositions of the material, state whether it's dangerous to health, and determine whether it's reactor or weapons grade. This is essential information, Ray says, for police to decide whether safety measures must be taken and whether a suspect should be kept in custody.

After this initial flurry of activity, ITU conducts an investigation, which can take up to 2 months, into the nuclear material's origins. This is where the real sleuthing comes into play. Researchers look for trace impurities that are hallmarks of a particular production process or even a specific factory.

Hot on the case. Ian Ray's nuclear detectives track the origins of seized radioactive material.

A sample's age may yield additional clues. The researchers use a thermal ionization mass spectrometer to compare the amounts of uranium or plutonium with their respective daughter products formed by radioactive decay. Calculations can be tricky: The half-life of plutonium-239, for example, is 20,000 years, and most of the samples are at most a few decades old, so only a minuscule amount of daughter isotopes (in the case of plutonium-239, uranium-234) are present.

Other useful information comes from comparing the abundance of oxygen-18 and oxygen-16 isotopes. When uranium ore is processed, it absorbs water. The ratio of oxygen isotopes in the water varies by latitude and proximity to the ocean, which can help pinpoint the region in which the material was produced. Even dust particles on the packaging can indicate where it has traveled.

All this information is analyzed using a database, developed in cooperation with the Bochvar Institute in Moscow, containing specifications on more than 1000 nuclear fuels produced worldwide for commercial reactors. (The database does not contain information on weapons-grade materials.) Researchers might, for example, feed in data on a uranium pellet, such as diameter, height, degree of enrichment, and concentration of certain impurities. The database would show possible matches, including the type of reactor that the pellet was intended for, the locations of such reactors, and the possible supplier.

Even if scientists can determine where seized uranium or plutonium comes from, it's not necessarily the end of the story. The last legal owner is supposed to take back such materials at its expense. But without access to a company's accounting system, it's tough to prove, and companies aren't usually willing to admit liability, says Lothar Koch, recently retired division head of ITU. **–S.L.**

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